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VEGETATION AND SEED BANK IN RELATION TO MICROHABITAT OF WADI NAGHAMISH, NORTH WESTERN COAST OF EGYPT

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This study investigated the soil seed bank composition and standing vegetation over five different microhabitats (terraces, springs, wadi bed, saltmarshes and sand dunes) of a coastal ecosystem along the North Western Coast of Egypt. The floristic composition and diversity of the soil seed bank, as well as its similarity with the standing vegetation varied among wadi microhabitats. Such variation could be attributed to differences in disturbance intensity among microhabitats and variation of soil factors along the micro topographic gradient. Sand dunes showed the highest species richness and size of soil seed bank, followed by wadi bed and then terraces. Moreover, the diversity index of the seed bank and its similarity with standing vegetation were significantly greater in salt marshes, followed by the terraces and the lowest in wadi bed. The species richness of seed banks was increased in the sand dunes than the other ones. Annual/perennial ratio and species richness of the standing vegetation were high terraces in comparison with the other microhabitat.

Keywords: Wadi Naghamish, vegetation, seed bank, microhabitats

Wadis are present in several phytogeographical regions of Egypt, particularly in the Eastern Desert, Sinai Peninsula and Mediterranean coast (Zahran and Willis, 2009). The wadi is a unique intrazonal landscape in arid and semi-arid regions of the world (Fossati et al., 1999), as they represent one of the most prominent desert landforms, which exhibit physiographic irregularities that lead to parallel variations in species distribution (Kassas and Girgis, 1964). These wadis are drainage systems for collecting water from extensive catchments areas such as hills, cliffs, slopes, etc. Accordingly, the water supply of a wadi is many times the recorded rainfall; with richer vegetation than other types of desert habitat.

The northern coastal ecosystem of Egypt develops along the Mediterranean Sea, have an uneven surface, creating many microhabitats that support different types of plant growth. In general, the distribution of plant communities in the north western coastal region is controlled by the topographic location, origin and nature of parent material and the intensity of human activities (Ayyad and Ghabbour, 1986).

Microhabitat can play a significant role in the movement of surface water over landscapes via its impact on infiltration and redistribution of surface water flows (Kishné et al., 2014 and Thompson et al., 2010). Moreover, surface microhabitat in arid regions is one of the major factors affecting seed dispersal and distribution (Boudell et al., 2002) and hence could affect the structure of soil seed bank. Various microhabitats could be identified in a wadi depending on the surface local topography; including wadi beds, banks, and terraces (Fossati et al., 1999).

Seed banks are an important component of desert habitats as they allow a great variety of species, mainly annuals, to survive. In such environments, soil seed banks are characterized by high spatial and temporal variability (Guo et al., 1998 and Kemp, 1989). The number of seeds per unit area in the soil seed bank in deserts varies remarkably among microhabitats, with more seeds in natural depressions and under trees and shrubs than in the open areas between woody vegetation (Guo et al., 1998 and Marone et al., 2004). Numerical differences in soil seed bank among microhabitats are consistent for several deserts (Kemp, 1989), but differences in seed bank species composition and diversity among desert.

MATERIALS AND METHODS

Wadi Naghamish is located 15 km east of Marsa Matrouh city and extends 20 km south from the coast. It is bounded by latitudes 31^{o} 06\` and 31$^{o}$ 16\` N and longitudes 27^{o} 10\` and 27$^{o}$ 22\` E, with a total area of about 25000 feddans, out of which more than 5000 feddans are cultivated land (Fig. 1). The floor slopes generally downwards in the northeastern direction from 180 m above sea level to sea level. Microhabitats can be recognized in the wadi. The climate of the study region is followed the Mediterranean region with the mean annual rainfall of about 120 mm with the rainy season occurring mainly from December to April (on average 24 mm rain-fall per month).

1. Soil Analysis

Three soil samples were taken randomly from each of 12 stands representing the Wadi bed, salt marshes, spring, sand dunes and terrace sites (3 stands/microhabitat). The selected stands also cover the within-microhabitat variations in vegetation. The samples were taken from a depth of 0-40 cm. The three samples were pooled together to form one composite sample for every stand. All procedures of the physical and chemical analysis of the soil samples are outlined by Ryan et al. (2001).

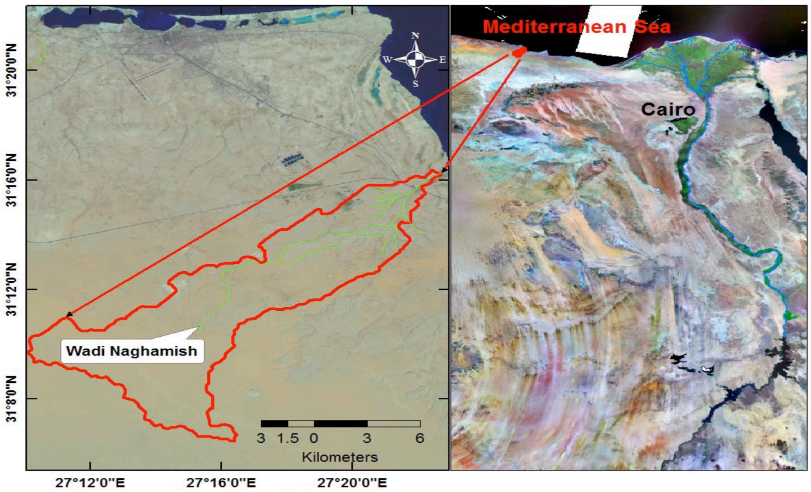

Fig. (1). Location map of the study area after (Abdel-Kader et al., 2004).

2. Above-ground Vegetation Sampling

The standing vegetation composition was determined in the 12 stands during April 2016. For each stand, the list of species is taken and the total vegetation cover as a percentage of ground surface was determined using ten randomly sampled 5 m^2 quadrats.

3. Soil Seed Bank Sampling

To assess the soil seed bank composition, 2 soil samples (25 cm × 20 cm and 5 cm depth) were randomly taken per each of the sampled stands. Therefore, a total of 12 samples were taken. Samples were collected at the end of the dry season (August 2016). The upper 5 cm of soil were considered as most seeds tend to be located in this depth (Gutterman, 1993). The germinable soil seed bank was assessed by monitoring seedling emergence as (Thompson et al., 1997). The method was used in this study to determine the species composition of the soil seed bank following (Gomaa, 2014). Emerging seedlings were identified, counted and removed. Unidentified taxa were counted and transplanted into individual pots and allowed to grow until identification was possible. After six months the experiment was stopped, as no more seedlings appeared for several consecutive weeks. For each stand, the species composition, mean density (number of seeds/m^2) and mean relative density of the species that constitute the germinable soil seed bank was determined. Plant nomenclature and identification followed (Täckholm, 1974 and Boulos, 2009).

4. Data Analysis

The differences in soil factors and vegetation variables among microhabitats were analysed by one-way ANOVA, followed by Tukey's posthoc test. The one-way ANOVA and correlation analyses were conducted using SPSS 25 for Windows. Similarity in species composition between seed bank and standing vegetation was assessed for each stand using the Motyka's similarity index (Mueller-Dombois and Ellenberg, 1974) was used to make comparisons between species composition of the soil seed bank and the above-ground vegetation in each stand: similarity index (%) = 2c / (a + b) × 100, where a is total number of species in the seed bank, b is the total number of species in the above-ground vegetation, and c is the number of species common to both seed bank and standing vegetation. The diversity of seed bank was measured in each stand using species richness, Shannon-index of diversity and Evenness index (Zhang, 1995).

RESULTS

1. Floristic Analysis of Above-ground Vegetation

A total of 69 species (50 perennials and 19 annuals) distributed among 63 genera and 22 families were recorded in the standing vegetation (Appendix). The largest families were Asteraceae (14 species), Chenopodiaceae (11 species), Poaceae (10 species), Fabaceae (5 species) and Polygonaceae and Zygophyllaceae (4 species).

2. Floristic Analysis of Seed Banks

The soil seed bank was composed of 33 species, belonging to 32 genera and 15 families. Species included 3 annuals and 30 perennials. The largest families were Chenopodiaceae (9 species) (see Appendix). The dominant species in the seed bank in terraces habitat was *Lycium shawii* (IV=23.9), around the springs, distributed in the wadi, the two co-dominated species *Cynodon dactylon* and *Thymelaea hirsuta* (IVs= 24.7 and 23.5, respectively). the co-dominated species *Hamada scoparia* and *Haloxylon salicornicum* are distributed along the Wadi bed (IVs= 18.7 and 18.3, respectively). Salt marshes microhabitat was dominated by *Juncus rigidus* (IV= 22.3), followed by *Arthrocnemum macrostachyum* and *Halocnemum strobilaceum* (19.2 and 16.3, respectively), while *Ammophila arenaria* and *Zygophyllum album* (44.3 and 37.7) were abundant in sand dune (see Appendix).

3. Variation of Soil Characteristics Among Wadi Microhabitats

The soil characteristics of the different wadi microhabitats are indicated in table (1). The soils of salt marshes showed significantly ($P <$ 0.05) higher values of organic carbon and moisture content compared to the soils of the other habitats. Sand fractions being highest in wadi wadi bed

(87.7%) and the lowest in salt marshes (11.4%). Moreover, soil silt and clay differed significantly (P < 0.05) among microhabitats, being highest in springs (20.7%), followed by terraces (11.9%) and then salt marshes (10.8%).

Table (1). Variations in soil characteristics (means ± SE) among wadi microhabitats.

Parameters	Microhabitats				
	Terraces	**Springs**	**Wadi bed**	**Salt marshes**	**Sand dunes**
pH	7.63±0.15^{b}	8.00±0.05^{a}	7.93±0.140^{ab}	7.76±0.12^{ab}	7.59±0.05^{b}
EC	1.07±0.29^{b}	1.41±0.18^{b}	1.45±0.050^{b}	2.93±0.09^{a}	0.31±0.02^{c}
Moisture %	1.17±0.02^{d}	5.33±0.24^{b}	3.43±0.202^{c}	15.10±0.99^{a}	0.98±0.07^{d}
Organic carbon %	0.04±0.001^{c}	0.12±0.03^{ab}	0.10±0.012^{b}	0.17±0.02^{a}	0.03±0.01^{c}
Sand fractions	75.70±4.50^{b}	63.40±0.17^{c}	87.70±0.860^{a}	11.40±0.35^{d}	84.90±1.41^{a}
Silt+Clay	11.90±3.20^{b}	20.70±2.02^{a}	7.56±1.220^{b}	10.80±0.26^{b}	1.85±0.05^{c}

Values in a row sharing the same superscript letter are not significantly different at the 0.05 level.

4. Variation of Diversity and Density of Seed Bank Among Wadi Microhabitats

As shown in table (2), the species richness varies significantly among habitats (P < 0.05). The sand dunes have the highest species richness (10) and the lowest in salt marshes (5.43). Shannon and evenness index is significantly higher (P < 0.05) in salt marshes (2.43) than in the other microhabitats (Table 2). The density of the seed bank differs significantly among habitats (P < 0.05). It is maximum in sand dunes (520 seeds/m^2), followed by wadi bed (397 seeds/m^2), while the lowest in salt marshes (86 seeds/m^2).

Motyka's similarity index between seed bank and aboveground vegetation is significantly higher (P < 0.05) in salt marshes (70.2%) compared to the other microhabitats (Table 2), the lowest one in springs (54.6%) of the 69 species recorded in the standing vegetation, only 42 species (74%) were present in the seed bank (Table 1). Ten were recorded only in the standing vegetation and not found in the seed bank. The species that were present only in the standing vegetation are mainly perennials, whereas all the species which were recorded only in the seed bank are perennials.

Table (2): Means ± SE of diversity indices and density of seed bank as well as the similarity between seed bank and the above-ground vegetation in the different habitats.

Parameters	Microhabitats				
	Terraces	Springs	Wadi bed	Salt marshes	Sand dunes
Standing vegetation					
Perennials richness	8.67±1.91	9.33±0.78	8.67±0.93	12.00±1.72	19.00±2.11
Annuals richness	5.33±0.71	5.33±1.23	2.67±0.58	4.50±0.82	5.00±1.01
Annual/perennials	6.15±2.70	5.71±1.05	3.08±0.79	3.75±0.81	2.63±0.92
Seed bank					
Shannon index	2.15±0.29	2.02±0.18	2.08±0.14	2.43±0.23	1.87±0.81
Evenness	0.63±0.08	0.59±0.05	0.61±0.04	0.71±0.07	0.54±0.04
Seed amount	248.30±10.70	148.70±16.50	397.00±7.64	86.00±6.92	520.00±8.12
Richness	7.00±2.01	6.67±0.82	8.10±0.91	5.43±2.67	10.00±3.21
Motyka's similarity index	62.90±4.71	54.60±2.25	55.70±4.93	70.20±3.42	58.80±+1.12

5. Effects of Microhabitats on Diversity and Size of Seed Bank

Species richness varied significantly ($P < 0.05$) among microhabitats. Sand dune habitat was the richest in species (10 species) and the lowest in saltmarshes (5.4 species). Shannon index was significantly ($P < 0.05$) higher in both saltmarshes and terraces habitat (2.43 and 2.15, respectively) than in sand dunes habitat 1.87). Evenness did not differ significantly among microhabitats (Table 2). The size of soil seed bank differed significantly among microhabitats ($P < 0.05$), being highest in sand dunes (520 seeds/m^2) and the lowest in both springs and wadi bed habitats (54.6 and 55.7 seeds/ m^2, respectively) (Table 2).

6. Vegetation-seed Bank Relationships

Among the 69 species that were identified in the standing vegetation, 33 (47.8%) occurred in the seed bank. Eleven species were observed only in the standing vegetation *Artemisia monosperma*, *Asparagus aphyllus*, *Centaurea calcitrapa, Heliotropium arabienase*, *Launaea spinosa*, *Lygeum spartum*, *Onopordon alexandrinum*, *Plantago major*, *Sporobolus pungens*, *Stipagrostis plumosa*, and *Varthemia montana*. Also, most of the annual species were observed only in the standing vegetation such as: *Bromus aegyptiacus*, *Cutandia memphitica*, *Daucus syrticus*, *Emex spinosa* and *Hordeum marinum*. Only one species observed in the seed bank, *Atractylis carduus*. As indicated by the Bray – Curtis similarity index (Table 2), the correspondence between standing vegetation and seed bank was high (>50%), however, the similarity was significantly greater for salt marshes (70.2.5%) in comparison with other microhabitats.

DISCUSSION

The microhabitats that undergo frequent disturbances, such as wadi bed and banks, are characterized by a preponderance of annual species. Annuals contribute to the seed bank more than perennials (Abdel Rahman and Batanouny, 1966). The higher soil contents of moisture, organic carbon, silt and clay of salt marshes micro-habitats, compared with sand dunes, may enhance the growth and seed production of the standing vegetation and consequently increasing the density of the corresponding soil seed bank. Martinez-Duro et al. (2012) related the species composition, density and species richness of soil seed bank in a semi-arid Mediterranean gypsum habitat to edaphic factors such as soil texture. Moreover, the effect of soil moisture (Leckie et al., 2000) on soil seed bank composition has also been reported. About 52.3% of species constituting the above-ground vegetation were absent from the seed bank. From a conservation point of view, these species should receive attention to protect them, because they are vulnerable to elimination. At the study area, there is a little correspondence between the soil seed bank and vegetation. These findings coincide with those of other researchers, who reported a poor relationship between standing vegetation and soil seed bank in desert communities (Khan, 1993 and Aziz and Khan, 1996). This may be due to effects of seed predation (Marone et al., 2000), lack of dormancy mechanisms (Esmailzadeh et al., 2011), successive years of drought, and the pre-dominance of vegetative reproduction (Baker, 1989). At the microhabitat level, the similarity between seed bank and vegetation was higher in salt marshes, followed by terraces than the other microhabitat. Communities with high annual/perennial ratios (in this study, terraces than the other microhabitat) show high similarity between seed bank and vegetation (Peco et al., 1998). Moreover, vegetation and seed bank composition are more similar in frequently disturbed communities compared with less frequently disturbed ones (Lavorel et al., 1991 and Luzuriaga et al., 2005).

Effects of the above-ground vegetation on the soil seed bank was also indicated by several significant associations between standing vegetation and seed bank parameters. The density and species diversity of the seed bank, measured as species richness and Shannon index, increased significantly with vegetation coverage, species richness and annual/perennial ratio (Gomaa, 2014). Increasing community coverage and species richness of standing vegetation could enhance the seed production of individual plants and the diversity of species composing the seed rain, which could increase the size and diversity of the corresponding soil seed bank. Significant positive correlation between vegetation and soil seed bank richness was documented by Martinez-Duro et al. (2012) in their study in a semi-arid Mediterranean gypsum habitat. The results also showed that the similarity between vegetation and seed bank increased with the annual/perennial ratio in vegetation.

The results corroborate previous generalizations about highly heterogeneous distribution of seeds in desert soils (Kemp, 1989 and Chambers and MacMahon, 1994). Most important, however, the study consistent differences in soil seed bank composition at the microhabitat scale of a coastal ecosystem.

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Appendix (1). List of species present in the above-ground vegetation (Veg.) and soil seed bank, and the mean density of seed bank (seeds m^{-2}) of species constituting the soil seed bank in the different microhabitats. (+) = present, − = absent.

Species	Terraces		Springs		Wadi bed		Salt marshes		Sand dunes	
	Veg.	Seed bank	Veg.	Seed bank	Veg.	Seed bank	Veg.	Seed bank	Veg.	Seed bank
Ammophila arenaria (L.) Link.	-	-	-	-	-	-	-	-	+	43.3
Anabasis articulata (Forssk. Moq.)	-	-	+	8.06	+	13.38	-	-	+	-
Artemisia herba-alba L.	+	7.01	+	-	-	-	-	-	-	-
Artemisia monosperma (Del.)	-	-	-	-	+	-	-	-	-	-
Arthrocnemum macrostachyum (Moric.) Moris et De/Ponte	-	-	+	13.70	-	-	+	23.20	+	14.8
Asparagus aphyllus L.	-	-	+	-	+	-	-	-	-	-
Asphodulus ramosus L.	+	12.60	-	-	-	-	+	7.01	+	27.3
Atractylis carduus (Forssk.) C. Chr.	-	-	+	9.32	+	10.28	-	-	-	-
Atriplex halimus L.	+	13.80	+	20.20	+	12.40	+	25.10	-	-
Calligonum comosum L'Her.	+	4.11	-	-	+	-	-	-	-	-
Capparis spinosa var. spinosa Lam	+	4.52	+	5.35	+	15.93	-	-	-	-
Centaurea calcitrapa L.	+	-	+	-	-	-	-	-	-	-
Cynodon dactylon (L.) Pers.	+	8.52	+	24.70	+	7.89	-	-	-	-
Deverra tortusa (Desf.) DC.	+	12.80	+	7.44	+	5.93	-	-	-	-
Echinops spinosissimus	+	9.95	+	5.14	+	-	-	-	+	-
Elymus farctus (Viv.) Runemark ex Melderis	-	-	-	-	-	-	-	-	+	12.9
Fagonia mollis Del.	+	-	-	-	-	-	-	-	-	-
Gymnocarpos decander Forssk.	+	10.80	+	4.31	+	7.46	-	-	-	-
Halocnemum strobilaceum (Pallas) M. Bieb.	-	-	+	6.60	-	-	-	18.80	+	27.9
Haloxylon salicornicum (Moq.) Bunge ex Boiss	+	19.60	+	8.48	+	18.30	-	-	-	-
Hamada scoparia (Pomel)	+	13.00	+	-	+	-	-	-	-	-
Heliotropium arabienase Fresen.	+	-	-	-	-	-	-	-	-	-
Juncus rigidus (Desf.) Fl. Atlant.	-	-	+	18.70	-	-	+	22.30	-	-
Launaea spinosa (Forssk.) Sch.Bip.	-	-	+	-	-	-	-	-	-	-

Lotus polyphyllus L.	-	-	-	-	-	-	-	-	+	-
Lycium shawii Roem. & Schult.	+	17.90	+	-	+	17.24	+	21.00	-	-
Lygeum spartum Loefl. Ex L.	-	-	-	-	-	-	-	-	+	
Marrobium vulgar L.	+	5.75	+	5.14	-	-	-	-	-	-
Nitraria retusa (Forssk.) Ach.	-	-	-	-	-	-	-	-	+	-
Noaea mucronata (Forssk.) Ach. & Sch.	+	-	+	9.14	+	14.63	+	-	-	-
Ononis vaginalis Vahl	-	-	-	-	-	-	-	-	+	-
Onopordon alexandrinum Boiss.	+	-	+	-	+	-	-	-	-	-
Pancratium maritimum L.	-	-	+	-	-	-	-	-	-	-
Peganum harmala (L.)	+	15.50	+	-	+	13.70	-	-	-	-
Phlomis flocosa D. Don	+	3.50	+	5.56	+	-	-	-	-	-
Phragmites australis (Cav.) Trin. ex Steud	-	-	+	9.32	-	-	+	18.40	-	-
Plantago major L.	-	-	-	-	+	-	-		-	-
Polygonum equisetiforme Sm.	+	7.58	+	-	+	14.30	-	-	-	-
Salsola tetrandera Del.	+	8.60	+	7.23	+	-	+	17.60	+	-
Salvia lanigra (Poiret)	-	-	+	-	+	17.60	-	-	-	-
Silybium marianum L.	+	5.54	-	-	+	15.06	-	-	-	-
Sporobolus pungens (Schreb.) Kunth.	-	-	-	-	+	-	-	-	+	-
Stipagrostis plumosa L. Munro ex T. Anderson	-	-	+	-	-	-	-	-	-	-
Suaeda pruinosa Lange	+	-	+	-	-	-	+	15.30	+	-
Suaeda vermiculata Forssk.	-	-	+	8.06	+	-	+	-	+	19.7
Thymelaea hirsuta (L.) Endle	+	12.20	+	23.50	+	15.90	-	-	+	-
Varthemia montana (Boiss.)	-	-	+	-	-	-	-	-	+	-
Verbascum sinaiticum Benth.	+	-	-	-	-	-	-	-	-	-
Zygophyllum album L.	+	7.79	-	-	-	-	+	19.10	+	37.7
Zygophyllum coccineum L.	-	-	-	-	+	-	+	12.80	+	16.4
Asphodelus viscidulus Boiss.	+	-	+	-	+	-	-	-	+	+
Bromus aegyptiacus Tausch	-	-	-	-	-	-	-	-	+	-
Cakile maritima Scop.	-	+	+	-	-	-	-	-	+	-
Chenopodium murale L.	+	+	+	-	+	-	-	-	-	+
Cutandia memphitica (Spreng.) K. Richt.	+	-	+	-	+	-	-	-	-	-
Daucus syrticus Murb	+	-	+	-	+	-	+	-	-	-

Emex spinosa (L.) Cambd.	+	-	+	-	+	-	-	-	+	+
Hordeum marinum Huds.	+	-	+	-	+	-	-	-	-	-
Iflago spicata (Forssk.) Sch. Bip.	+	+	+	-	+	-	+	-	-	-
Lolium perenne L.	+	-	+	-	+	+	-	-	-	-
Melilotus indicus (L.) All.	+	-	+	+	+	+	-	-	-	-
Ononis serrata Forssk.	+	-	+	-	+	-	+	-	-	+
Pancratium sickenbergeri Ach.	-	-	-	-	-	-	-	-	+	-
Plantago squarrosa Murray	+	-	+	-	+	-	-	-	-	-
Reichardia tingitana (L.) Roth	+	-	+	-	+	-	-	-	-	+
Rumex pictus Forssk.	+	-	+	-	+	-	+	-	-	-
Senecio vulgaris L.	+	-	+	-	+	-	+	-	-	-
Sonchus oleraceus L.	+	-	+	-	+	-	-	-	-	+
Xanthium spinosum L.	+	-	+	-	+	-	-	-	-	

علاقة الغطاء النباتى، بنك البذور وتباين الموائل الدقيقة لوادى نغامش، الساحل الشمالى الغربى لمصر

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وضحت هذه الدراسة تركيب محتوى التربة من البذور وعلاقته بالغطاء النباتي الموجود (القائم) في عدة موائل مختلفة (المدرجات، والعيون، ومجرى الوادي، والمستنقعات المالحة، والكثبان الرملية) للنظام البيئي الساحلي في الساحل الشمالي الغربي لمصر. حيث تباين التركيب النباتي وتنوع محتوى البذور في التربة، وكذلك التشابه مع الغطاء النباتي في الموائل الصغيرة للوادي. ويرجع هذا التباين والتشابه إلى الاختلافات الواضحة بين الموائل الدقيقة وعوامل التربة على طول التدرج الطبوغرافي للموائل الدقيقة في الوادي. أظهرت الكثبان الرملية نسبة عالية في تركيب حبيبات التربة، تلتها القنوات ثم المستنقعات الملحية. علاوة على ذلك، أظهرت الدراسة أن الكثبان الرملية أعلى ثراء في الأنواع النباتية وحجم محتوى البذور في التربة، أتبعها مجرى الوادي ثم المدرجات. علاوة على ذلك، كان مؤشر تنوع محتوى البذور في التربة ومدى التشابه مع النباتات الدائمة أكبر بكثير في المستنقعات الملحية، أتبعها المدرجات وأقل مؤشر للتنوع كان في مجرى الوادي. كانت نسبة الأنواع الحولية/المعمرة وأيضًا ثراء الأنواع النباتية مع الغطاء النباتي الموجود (القائم) في بيئة المدرجات مرتفعة مقارنة بالموائل الأخرى.